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ABSTRACT

Severely physically disabled people can be helped to reach their goals in educational, vocational, and personal pursuits through appropriate use of current technology. The expressive communication needs of people without functional speech can be met through an analysis of selection techniques, processing, and outputs. Examples of new systems include Minspeak, an approach which uses normal language processes. Alternatives for providing computer access include a portable battery powered device mounted on a wheelchair or a system using head movement to make selections on a keyboard matrix. Persons with severe physical limitations can operate electrical devices in their environment through a system using a microcomputer, peripheral hardware, and an appropriate program. An area of great need is the integration of communication, computer access, and environmental control with mobility. One such system under development features commercially available components, including an optical headpointer, a joystick simulator, and a wireless data telemetry system. (CL)

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INTEGRATING COMMUNICATION, COMPUTER ACCESS, ENVIRONMENTAL CONTROL & MOBILITY

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ABSTRACT

The technology of today offers the people of our society the opportunity to reach levels of achievement never before possible. We all use machines for communication, transportation and entertainment and in performance of our jobs. Technical aids are also available for people with physical handicaps to help them reach goals in educational, vocational and personal pursuits. Through the use of appropriate aids, individuals who are physically handicapped can realize an overall improvement in the quality of life.

Two primary population groups that can be debilitated by physical disability are:

a) high level spinal cord injury (SCI) and
b) severe involvement with cerebral palsy (CP).

These population groups appear to represent the largest groups with needs in the area of physical disability; people with other diagnoses also benefit from the use of technical aids designed around the needs and capabilities of these two groups. Other disabilities include muscular dystrophy, multiple sclerosis, amyotrophic lateral sclerosis and others.

The needs of these population groups can be divided into four areas:

a) Communication
b) Computer Access
c) Environmental Control
d) Mobility

Of the four areas, communication is by far the most important. For nearly everyone, achievement is closely tied to the ability to communicate. The more effective a person's communication skills, the more promising that person's future. Conversational communication is generally not a problem for the SCI population as they retain their speech. For the person with severe cerebral palsy, communication should be the first need addressed.

The transition to an information based society has greatly assisted people with physical handicaps. These people were a burden in the days of agricultural or industrial based society. Today, many disabled persons can be productive. A physical handicap does not have to affect a person's ability to access, process and communicate information. Today

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no person should be provided with a communication system, environmental control or powered wheelchair without considering an access to computers.

After communication and computer access, a person should be provided with a means of operating various appliances in his surroundings. An environmental control system satisfies this need.

Finally, people need to be mobile. Most people with high level SCI and severe cerebral palsy need a powered wheelchair to be mobile. The issue of wheelchair control needs to be addressed.

Control Interfaces

The control interface is that portion of a technical aid or aid system through which the user operates the aid or system. It may be an integral part, as in the case of a built-in keyboard, or it may be a separate component. Figure 1 represents a person using a technical aid to perform a task.

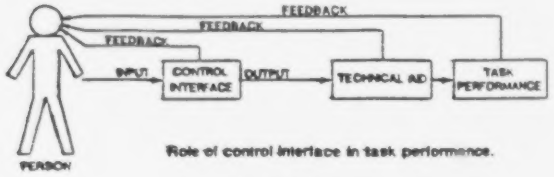


FIGURE 1.

Control interfaces can be categorized in a number of ways. For the purpose of this discussion, they are categorized in two areas:

a) Input from the user.
b) Output to the technical aid.

Input to the control interface is provided by the person. This requires that the person have some controllable capability that can be monitored by the control interface. This capability is usually within one of the following areas:

A. Physical Movement
B. Pneumatic
C. Myoelectric
D. Sound

As indicated in Figure 1, helpful feedback can be provided to the user at various points in the performance of a task. One source of this feedback is the control interface. The simple click of a switch that tells the user it has been activated can significantly enhance performance. Tactile feedback of a keyboard, audible beeps and indicator lights are other examples of how this important function can be implemented. As a person becomes familiar with the operation of the device, proprioceptive feedback within the body may further enhance performance.

In some cases, no standard control interface will provide optimum performance. In this situation, a custom unit should be designed and fabricated.

While effectiveness in task performance is emphasized other factors also influence the selection and application of a control interface. These include psychological issues, environment, appearance, set-up time, training effort, maintenance, cost and other practical matters. Frequently, compromises are made between one or more of these factors and the performance of the system. However, since optimal performance should be the primary goal, any compromises should be recognized and communicated to all, including the technical aid user.

Communication

This area addresses the expressive communication needs of people without functional speech. These people, generally, are physically disabled to the extent that they cannot use pen or pencil, type, or sign. Consequently, their ability to express themselves is severely impaired.

The goal for providing a person with a communication aid should be to achieve the fastest, most effective communication possible. As previously

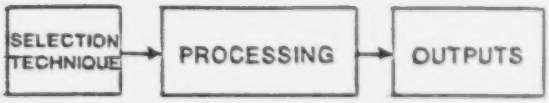
indicated, a person's life achievement is largely determined by his ability to communicate. The process of selecting and applying a communication aid, thus, becomes very important.

Three factors determine the expressive speed of a person using a communication aid:

a) Selection speed
b) Number of selections needed
c) Amount of information retrieved

Selection speed refers to the speed with which the user can make a selection from the array of possible selections. For example, using a keyboard, how long does the user take to locate and activate a key? Number of selections needed refers, to the number of selections that need to be activated to retrieve information. The amount of information retrieved is the last issue. Typical systems might offer only a single letter or other character, a string of characters, words, phrases or complete sentences. All three of these issues determine the rate a person will be able to communicate. Communication can be divided into three areas as indicated in Figure 2:

a) Selection techniques
b) Processing
c) Outputs.



EXPRESSIVE COMMUNICATION SYSTEM

A number of selection techniques have been developed to address the wide range of physical capabilities present in people with severe communication impairment. These selection techniques can be divided into the following classifications:

a) Direct Selection
b) Scanning
c) Encoding

The selection technique that provides the best performance for a particular person will be a function of the physical capabilities exhibited by that person.

For most people with the physical capability to use a direct selection operating technique, it can offer the fastest performance.

While scanning techniques are relatively slow by comparison, they have the advantage of very little physical demand on the user.

Typically, older electronic communication aids were designed to use only one selection technique. Today, aids based on microprocessor technology can operate using different techniques. For both the client and the rehabilitation professional this can be an important asset. When selecting an aid, consideration must be given to the future needs and capabilities of the user. A brain stem injury, for example, may improve physically with time, however, a person with a progressive neurological disorder is expected to lose physical capability. If the communication aid cannot change, it will become useless and/or inappropriate. Processing, the second area in the topic of communication, addresses the way the selection made by the person is used to generate communication.

In the simplest systems, there is no processing. Each selection corresponds to a fixed character or character string. Better systems provide the programming of character strings.

The recent state-of-the-art in commercially available systems is the concept of levels. With this approach, each location in an array of selections could have many meanings. The primary meaning, referred to as the base level, could be retrieved with a single selection. However, any of the other meanings could be retrieved by first selecting a new level, then selecting from within that level. This would correspond to having an entire vocabulary in a book, for example of 100 pages, each with 128 entries. The first

page would be fixed and offer access to the ASCII character set. The other 99 pages would have entries of character strings built from the first page. While this system has proven to be functional, it does have limitations that were not immediately obvious. A major fault is the difficulty for the user to remember where particular strings have been stored. The concept of levels and location (pages and entries) is not conducive to memory; it is too arbitrary.

A generalized concept called abbreviation expansion has been promoted by the Trace Center, University of Wisconsin, Madison. This system is an attempt to better match a person's natural language process. With this approach, frequently used, longer character strings are represented by short character strings. For example, "Hello. How are you?" could be represented by "HH?".

Another system, called Minspeak, has been proposed by Bruce Baker, a linguist now working in this field. Minspeak, now commercially available from the Prentke Romich Company, is a further attempt to speed communication by making use of normal language processes.

Minspeak is based on five basic principles:

a. Full sentences contain more information than smaller units of communication.
b. Much of a person's routine communication needs can be satisfied by a set of carefully chosen fixed sentences.
c. Sentences can be summarized by a sequence of concepts.
d. Concepts can be represented by symbols.
e. Logical organization of sentences can further increase communication speed.

Although the concept of Minspeak is more difficult to understand and may require a greater time investment to implement, Minspeak appears to offer performance well beyond its "level and location" based predecessors. Microcomputer technology has permitted the linguist's proposal to become reality. Without that technology, it would only be an idea.

The last area within the topic of communication is that of outputs. Typical communication aid outputs include:

a) Correctable display
b) Printer
c) Speech
d) Data

The combination of these appropriate for a particular user will be a function of the expected needs of that person.

Microcomputers frequently contain hardware features that permit them to be used as communication aids. Indeed, attempts have been made to develop programs that make particular units useful as such. However, there has been no widespread success in this area. The issues that must be considered in such a venture are complex. People who know microcomputers generally don't appreciate the complexity of the issues relating to physical, psychological and linguistic capabilities and needs of the users. Further, the process of disseminating software and providing the education and support that is needed can be difficult. Also, the volatility of the microcomputer market has discouraged software developers from making investments in this area. The recent withdrawal from the market by Texas Instruments and Timex are prime examples.

If a microcomputer were to be successfully programmed for use as a communication aid, the cost of a complete system to the user would still be substantially higher than common for mass market items using the same microcomputer. The reason is that very little of the cost of a communication aid is the cost of producing the hardware. The majority is the cost of development and the provision of services.

Frequently, microcomputer enthusiasts will develop a system for a particular user. While this approach does provide something for someone who had nothing,

it almost always results in a system that is less effective than the best possible. Consequently, the level of achievement of the user will be limited. In addition, new ideas and techniques are continually being developed. When commercially available systems are used, the development of updates is practical and older units can be improved. Routine service is another issue. Extreme care must be taken to consider the potential result of this approach.

Computer Access

The information revolution is under way. The tool of the information age is the computer. Today the microcomputer is used in a wide variety of applications. Many tasks that used to be performed manually are now much more effectively accomplished using computers. Many jobs are being created around the need to access, process and communicate information. For people with physical handicaps, this situation opens up many opportunities and offers new levels of personal achievement. However, if those people are unable to use computers, not only will they be deprived of those opportunities and achievement, they will be taking a relative step backward in our society.

For example, the microcomputer is now common in the public school classroom. Able-bodied students use it as part of their normal education. if the disabled student is unable to use it, he is deprived of this new educational opportunity available to the rest of the students.

Perhaps the most common productive application of the microcomputer is a word processing system. This function is useful in educational, vocational and personal activities. It may be more valuable to people with severe physical handicaps than to able-bodied persons as the disabled often don't have the alternative of writing or typing.

Computer access can be accomplished in different ways. Of course, the ideal situation is the use of a standard keyboard. Sometimes the use of a mouthstick or head mounted pointer permits this. For those unable to operate the standard keyboard, alternatives must be sought. One of the easiest approaches is the addition of a keyguard to the keyboard. A keyguard consists of a flat surface mounted over the keyboard to support the hand. This permits the person with cerebral palsy to stabilize the hand. A hole over each key permits the keys to be activated. For keys that must be pressed in combination with another key, such as SHIFT and CONTROL, latching mechanisms can be included that will hold them down. This feature is needed for a person who can use only a single finger, mouth stick or headpointer. To enter a CONTROL "S", for example, the user would first press CONTROL, then "S", then release the CONTROL key. For people who are unable to operate even a guarded keyboard, other alternatives must be sought. Sometimes a control interface can be connected directly to the computer, perhaps through the game paddle ports or in parallel with one of the keys. The program can then be modified or a special program can be written to monitor the status of the control interface. Generally, the modification of standard software or the development of custom software to duplicate the function of standard software has serious faults. The main problem is that the investment is only useful for that one program and the process must be duplicated for each new program. Also, the overall performance will almost always be less than the best possible. A far better approach is to modify the hardware to permit access by the disabled person. Most software is written under the assumption that the user will enter information through the computer keyboard. Therefore, a generic solution to the problem is to provide the disabled person with a means of entering information

into the computer in a manner that lets the computer think the information is coming from the keyboard. Hardware is available for several microcomputers that will permit this. The device is called a keyboard emulator.

Keyboard emulators are typically connected between the keyboard and the central processing unit (CPU). They accept ASCII (American Standard Code for Information Interchange) characters from an external device and enter them into the computer as if they are keystrokes on the keyboard. Normally the keyboard remains active. Therefore, in a classroom the computer can be used both by able-bodied and disabled students.

At this point, the issue is one of providing disabled persons with a means of generating ASCII characters. Several alternatives exist. An expressive communication aid may be able to provide the characters.

The communication aid, which should be a portable battery powered device, is often mounted on the user's wheelchair. It can be connected to the keyboard emulator using a cable. However, a wireless telemetry system would provide a cleaner environment. If the user operates a powered wheelchair, wireless data telemetry permits independent mobility.

For the person without a communication aid with data output, other alternatives are available. A person with high spinal cord injury normally would not need a communication aid. One approach for that person could be blowing and sucking on a tube to enter dots and dashes in Morse code for the ASCII convertor. Two switch input using an Apple computer has been developed at Northwestern University. Another approach could be the use of head movement to make selections on a keyboard matrix.

A microcomputer with an appropriate program could be dedicated to the function of an ASCII generator. The program running on this computer would monitor a control interface operated by the user and would respond with ASCII characters or strings.

Environmental Control

After communication and computer access, the next need of a person with a severe physical disability is the operating of various electrical devices in his surroundings. Typical environmental control systems can answer and dial the telephone, turn powered devices on and off, dim lamps, position the electric bed, and operate other special accessories such as intercoms, nurse's calls, page turners, television channel selectors, etc.

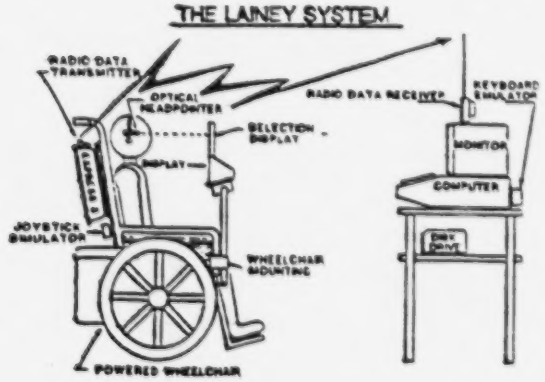
Today, operations from the premise that everyone needs to be able to operate a computer, the approach to environmental control has changed. Environmental control systems are available that are controlled through ASCII characters. This means that the person who uses a computer or is able to generate ASCII characters now has the power of an environmental control system without the need for any additional physical capability.

As with communication systems, it is possible to create an environmental control system using a microcomputer, peripheral hardware and an appropriate program. While the performance of an environmental control is not nearly as important as the performance of a communication aid or computer access system, there are still some issues that should be considered. One is operation during a power failure. When power fails, most accessories will not be functional because of their dependence on electricity. However, a function that may be quite important, particularly for a person with severe physical disability, is the telephone. If the environmental control is based around a "mains" powered microcomputer, then nothing else will function when power fails. Commercial environmental controls generally offer a standard or optional battery backup to keep the telephone function intact.

Integrating Communication, Computer Access and Environmental Control with Mobility

Much work has been addressed to the separate areas of communication, computer access, environmental control and mobility. The first three of these areas inherently integrate. However, little has been done to integrate these with the area of mobility. For people with less severe levels of impairment, integration is not necessary. These people have enough physical capability to be able to use the conventional solutions to the separate problems. But people with limited capabilities may only be able to use one technical aid. For example, since a person's potential for achievement is closely tied to the ability to communicate, it makes sense to use the total physical capability toward that end. Without integration, no capability may be left for the control of other aids. If the control of the technical aids addressing all areas of need can be integrated, then the same capability can be used in all areas.

Based on work completed by the Rehabilitation Engineering Center at the University of Tennessee in Memphis, Prentke Romich Company is pursuing this area. PRC is presently under contract with the United States Department of Education to assemble, evaluate and develop a marketing plan for such a system.



The Lainey System, named after a prototype user, primarily uses commercially available components. Additional components are soon expected to become commercially available. The first system demonstrated uses an optical headpointer as the control interface and is based around the PRC Express 3 or Minspeak. A standard wireless data telemetry system and keyboard emulator provide computer access.

Powered wheelchair control is provided by a joystick simulator. The original powered wheelchair electronic control package is retained. The rationale for this has facets. First, the powered wheelchair manufacturer knows the power and control requirements of the wheelchair and motors and, therefore, should be able to develop a more reliable and effective system. Second, when a failure does occur, the local dealer is in a much better position to quickly service the system as replacement parts are more likely to be stocked locally.

Computer access is provided by a wireless data telemtry system. The transmitter is connected to the Express 3 or Minspeak and the receiver is connected to the computer keyboard emulator.

Environmental control, while not a priority of classroom students, is important at home. Using an environmental control system that can accept ASCII characters, that function is available to the user without any additional physical capability requirement. Using the wireless telemetry, for example, the user in his living room could transmit a code to the environmental control in the bedroom which in turn transmits over the power line to the power control module, turning the stereo beside him on.

At the time of this writing, Prentke Romich Company plans to make this entire system available.

Summary and Challenge

Even with all of this exciting

technological progress, new problems are being created. Now that functional technical aids are available, we must address the task of getting them to the people for whom they have been created. First, is awareness building. People who need, or who have clients who need, technical aids must become familiar with the capabilities that these systems offer. Those rehabilitation professionals who select and apply technical aid systems must then learn how to do so in a manner that best serves the interests of the client. Finally, funding for technical aids and the necessary corresponding services must be provided. In all of these areas we are making progress, but more work is needed.

For people with severe physical disabilities there has never been a better time in history. As never before, these people can be active and productive members of our society. With technical aids in the areas of communication, computer access, environmental control and mobility, people can set and achieve goals in educational, vocational and personal pursuits.